

[54] METHOD OF MANUFACTURING A SYNCHRONOUS ELECTRIC MOTOR WITH MAGNETISED ROTAR

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[75] Inventors: Claude Oudet, Besancon; Gilbert Drey, La ChauX-De-Fonds; Norbert Veignat, Besancon, all of France

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[73] Assignee: Portescap, ChauX-DeFonds, Switzerland

[21] Appl. No.: 376,174

Primary Examiner—Carl E. Hall
Attorney, Agent, or Firm—Willian, Brinks, Olds, Hofer, Gilson & Lione

[22] Filed: Jul. 3, 1989

Related U.S. Application Data

[62] Division of Ser. No. 117,200, Aug. 6, 1987, Pat. No. 4,866,323.

[30] Foreign Application Priority Data

Dec. 6, 1985 [CH] Switzerland 5192/85

[51] Int. Cl.⁵ H02K 15/02

[52] U.S. Cl. 29/596; 29/598; 310/42; 310/156; 310/268

[58] Field of Search 29/596, 598; 310/42, 310/43, 156, 268

[57] ABSTRACT

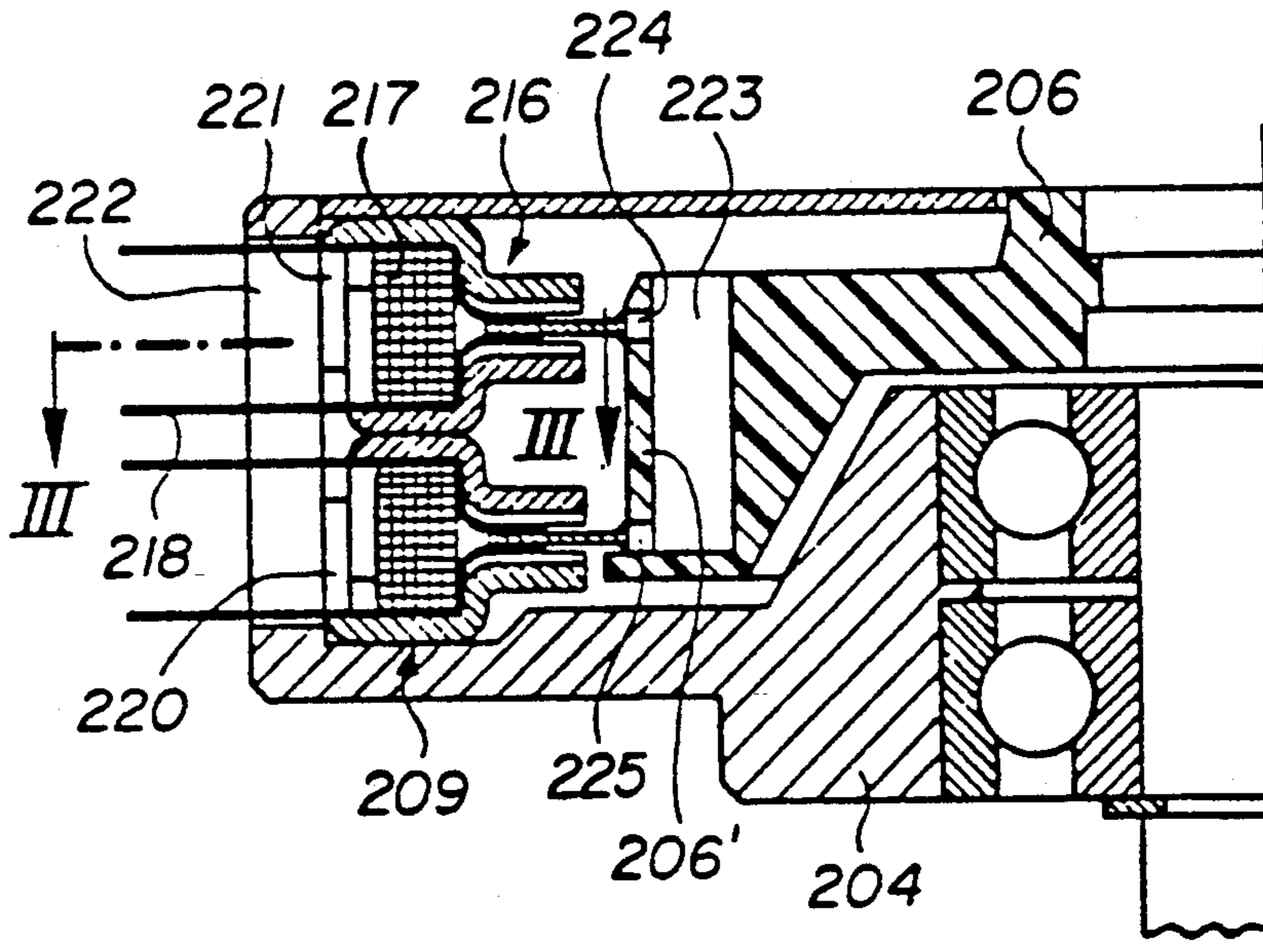
A method is disclosed for manufacturing a synchronous electric motor which includes at least one flat annular rotor part which is magnetized so as to present at least one series of magnetic poles arranged along a flat annular zone of the rotor part. The rotor part is fixed by at least one rotor-supporting part on a shaft of the motor. The motor shaft is mounted for rotation with respect to at least one stator assembly which includes at least two stator parts. The stator parts include pole parts arranged so as to form, in their assembly, an air-gap in which are disposed the magnetic poles of the rotor part. At least one electric control coil is coupled with one or more pole parts.

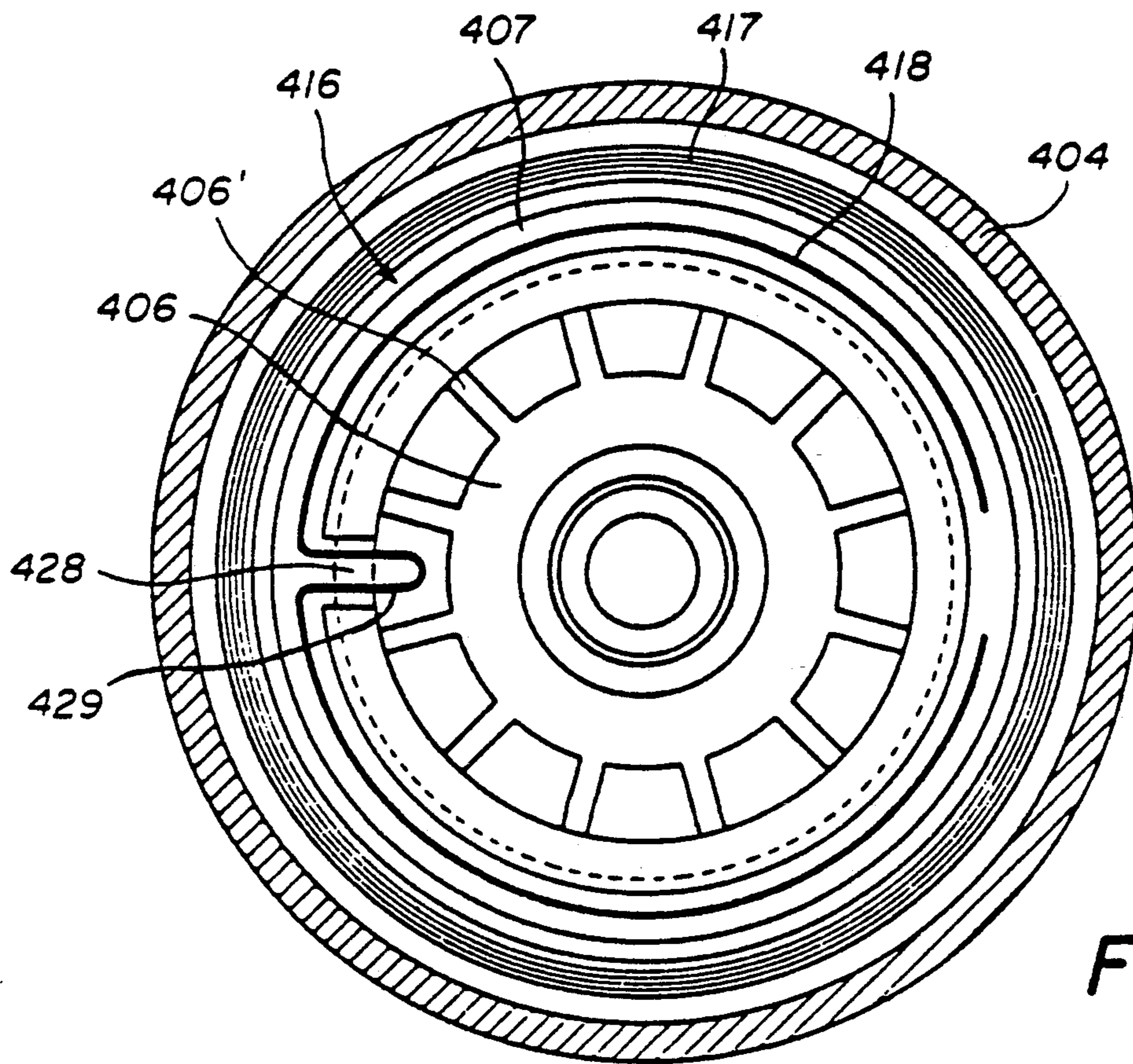
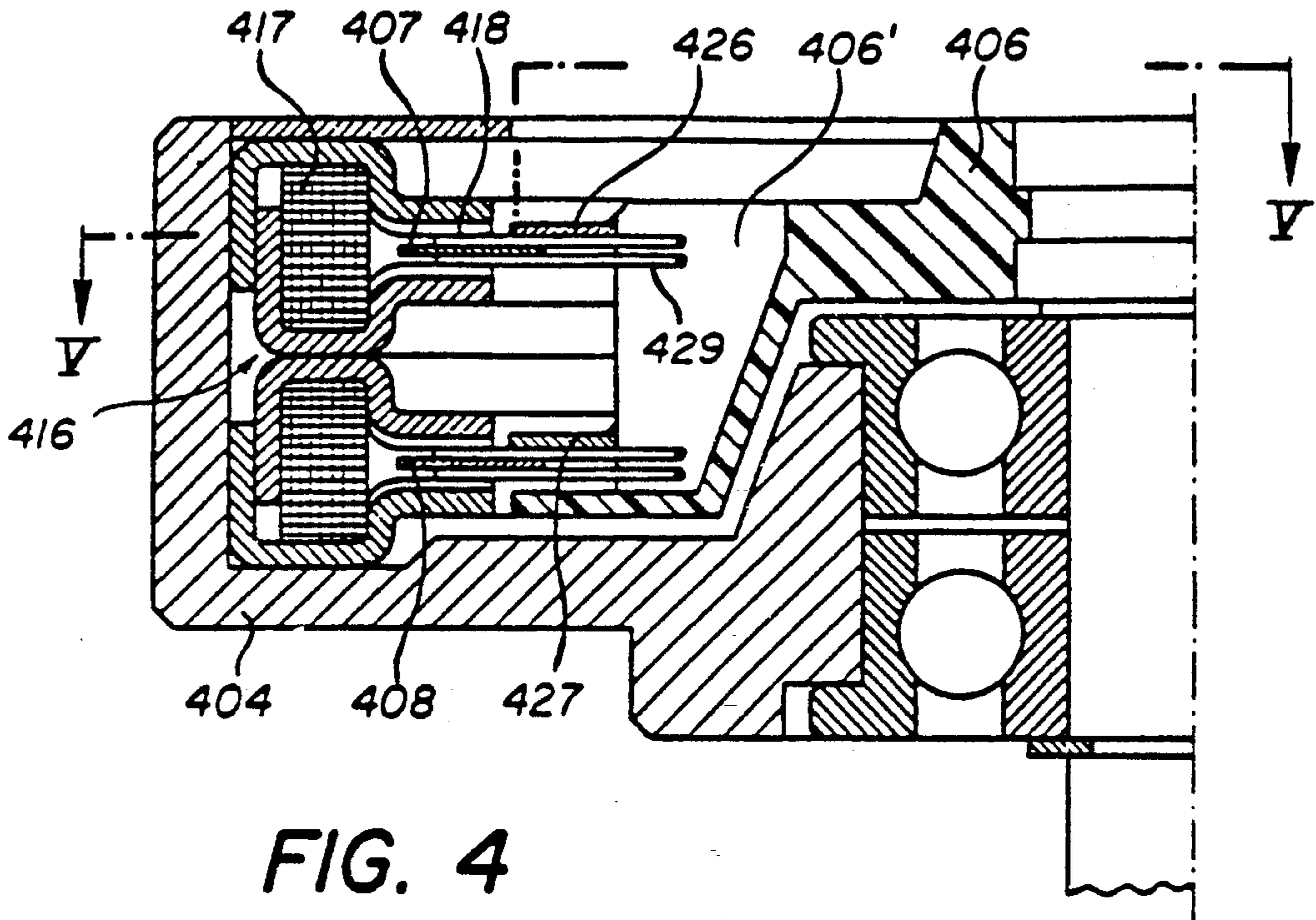
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U.S. PATENT DOCUMENTS

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12 Claims, 2 Drawing Sheets





**METHOD OF MANUFACTURING A
SYNCHRONOUS ELECTRIC MOTOR WITH
MAGNETISED ROTAR**

This is a division of application Ser. No. 07/117,220, filed on Aug. 6, 1987.

The present invention relates to a synchronous electric motor comprising a least one rotor part of essentially flat annular form, magnetized so as to present at least one series of magnetic poles disposed regularly along a planar annular zone, the said rotor part being fixed by means of at least one rotor-supporting part on a motor shaft mounted to be rotatable relatively to at least one stator assembly, the stator assembly comprising at least two stator parts of a magnetically permeable material, these forming, being fast with or being coupled with pole parts arranged so as to form, in their assembly, a variable air gap along at least one portion of an annular space in which are disposed the magnetic poles of the rotor part, the stator assembly comprising, in addition, at least one electric control coil coupled with one or several of the said pole parts. Such a motor is described, for example, in International Patent Application No. WO 85/02503.

The invention has for its object to provide a motor of the aforementioned type, of which the conception, while using usual elements such as standard ball bearings for the mounting of the motor in relation to the stator assembly, facilitates the fabrication of this motor, particularly at the time of assembly, and makes it possible to achieve in a simple and economic fashion a very good precision in the positioning of the rotor part with respect to the stator assembly.

To this end, the motor according to the invention is characterized in that the fixing of the rotor part on the rotor-supporting part is effected in such manner as to permit, when assembling the motor, a positioning of the rotor part in the axial direction and also an angular positioning of this latter relatively to the direction of the motor axis.

Preferably, the stator assembly comprises separate stator parts which form part of a same magnetic circuit, the stator assembly being arranged so as to permit, at the time of assembling the motor, a positioning of the stator parts relatively to one another in the axial direction. In this case, the stator parts which form part of a same magnetic circuit may be interconnected, directly or by means of a yoke part, so as to form a magnetic joint constituted by contact surfaces parallel to the axis of the motor shaft. More particularly, the stator assembly may be formed by two coaxial annular stator parts of like form, each having at least one first and one second cylindrical wall portion, the internal diameter of the first wall portion being equal to the external diameter of the second, the two stator parts being joined in such manner as to be fitted one within the other by the said respective first and second wall portions.

The invention is more particularly applicable to a motor in which the rotor part is present in the form of an annular disc of small thickness with respect to its external diameter and is magnetized axially, and the stator assembly comprises pole parts disposed on both sides of the rotor part.

Preferably, the stator assembly and/or the rotor supporting part comprise at least one access opening communicating with the air space between the rotor part and the pole parts, this opening being accessible from

outside the stator unit assembled with the motor shaft provided with the rotor part.

The invention also has for its object a method of fabricating such a motor, in accordance with which, first of all, the motor shaft provided with the rotor-supporting part is assembled with an assembly of pole parts which have to be disposed facing a corresponding flat annular zone of the respective rotor part, in such manner that the ends of these perpendicular to the axis of the motor shaft, that the annular rotor part is placed in position by disposing at least one spacer element of a determined thickness between the latter and the ends of at least one part of the said pole parts, that the rotor part is fixed on the rotor support and that the spacer part is withdrawn or removed from the space between the rotor part and the said pole parts. More particularly, the spacer part may be a sheet of thermo-retractable plastic material, a sheet of a material capable of being dissolved in a chemical solvent or a metallic wire of essentially circular form.

Other features of the invention will become apparent from the claims formulated and from the following description of different embodiments given by way of example and illustrated in the accompanying drawing, in which:

FIG. 1 is an axial section of a first embodiment of the motor according to the invention,

FIG. 2 is an axial section of an embodiment which is similar to that of FIG. 1,

FIG. 3 is a partial sectional view along the line III—III of FIG. 2,

FIG. 4 is an axial section of another embodiment of the motor, and

FIG. 5 is a view, partly in section, along the line V—V of FIG. 4.

FIG. 1 illustrates a first embodiment of a two-phase motor, comprising two stages, each stage representing one of the phases of the motor.

A shaft 1 of the motor is mounted to be rotatable, by means of the two ball bearings 2, 3, in a stator support 4. In order to avoid any axial play of the shaft, the axial play of the ball bearings is taken up and the inner race if these latter is welded onto the shaft or the shaft is fixed by means of a circlip 5 and shims (not shown), disposed between the shaft and the adjoining race of the bearing 2. A shoulder 1' of the shaft 1 serves as support for the inside race of the bearing 3.

A rotor-supporting part 6 of plastic material is made fast with the shaft 1, for example, by casting or moulding, as shown in FIG. 1. This rotor-supporting part has a certain number of ribs 6', for example, twelve in number, of which the peripheral parts are engraved in a cylindrical surface which is coaxial with respect to the shaft 1. Two rotor parts 7, 8, in the form of a thin annular disc, are fixed by bonding on the peripheral parts of the ribs 6', the positioning of these rotor parts being described in greater detail hereafter. The two annular discs 7 and 8 are made, in a manner which is well known, of a magnetizable material such as samarium-cobalt, and they are magnetized axially so as to present magnetic poles on each of their flat surfaces, for example, poles of which the polarity alternates peripherally of the disc.

The stator support 4 has an annular reference surface 4', which is flat and situated in a plane perpendicular to the axis of the shaft 1 mounted in the stator support. A first stator assembly 9 comprises a lower stator part 10 and an upper stator part 11 of a magnetically permeable

material, these two stator parts being of annular form and having a cylindrical contact surface 12 parallel to the axis of the motor shaft, so as to form a magnetic joint between the parts 10 and 11. The inside parts 13, 14 of the stator parts constitute assemblies of axially spaced polar parts and thus present a toothed profile in the direction of the circumference, so as to form an air-gap of variable height between the parts 13 and 14.

An electric control coil 15 of annular form is disposed between the stator parts 10 and 11 in such manner as to be coupled with the corresponding pole parts.

A second stator assembly 16 is arranged in quite a similar manner to the stator assembly 9 and comprises an electric control coil 17. The rotor parts 7 and 8 are respectively disposed in the air-gaps formed by the stator assemblies 16 and 9.

It is also to be seen in FIG. 1 that the stator assembly 16 is resting on the stator assembly 9, a planar annular contact surface being provided for defining the position and particularly the orientation perpendicularly of the axis of the shaft 1 of the stator assembly 16. The stator support 4 comprises a lateral wall, of which the interior cylindrical surface permits the centering of the stator assemblies relatively to the motor shaft. Finally, a cover 17 resting on the stator assembly 16 and closing the housing formed by the stator support 4 can be seen in FIG. 1.

When assembling the motor, the shaft 1 provided with the rotor-supporting part 6 is first of all mounted in the stator support 4 in the manner already referred to above. The lower stator part 10 of the stator assembly 9 is then positioned on the reference surface 4' and a sheet of a heat-retractable plastic material 18 is then placed on the ridges of the toothing of the part 14, which sheet may be of annular form and have a determined thickness, for example, of seven hundredths of a millimetre. Such a heat-retractable material is, for example, ordinary PVC.

The coil 15 is then positioned on the lower part 10 of the stator assembly and the sheet 18 placed in the bottom of this latter. The lower rotor part 8 is then placed on the ridges of the toothing of the part 14, on which ridges is positioned the sheet 18. The rotor part 8 may, to this effect, be displaced freely along the support part 6, i.e. along the peripheral parts of the grooves 6', relatively to which it is centered. The separation sheet 18 thus determines, by its thickness, the axial distance between the rotor part 8 and the part 14 and, in addition, it assures that the rotor part is disposed parallel to the reference surface 4' and thus perpendicular to the axis of the motor shaft.

The sheet 18 is then folded around the coil 15 in such manner that the edge or margin of the sheet 18 is placed on the upper surface of the rotor part 8. The upper part 11 of the stator assembly 9 is then positioned on the sheet 18 covering the coil 15 and the rotor part 8. The sheet 18 thus determines the axial spacing between the rotor part 8 and the part 13 of the stator assembly. In this position, the rotor part 8 is stuck or fixed by another means on the rotor support part 6 and the two stator parts 10 and 11 are also fixed, for example, by adhesion or welding, relatively to one another and relatively to the stator support 4.

The upper stator assembly 16 and the corresponding rotor part 7 are assembled and fixed in a manner similar to that which has just been described, the upper surface of the stator part 11 serving as reference surface for the lower part of the stator assembly 16.

When the two stator assemblies and the two rotor parts are fixed in their respective positions, an electric current is caused to pass through the coils 15 and 17 in such a manner as to produce a heating of the plastic sheets surrounding these coils and to cause the retraction of these sheets from the air-gaps of the two stator assemblies.

Instead of using a heat-retractable plastic material, it is also possible to employ a plastic material capable of being dissolved in a suitable chemical solvent, which is introduced into the air-gaps for obtaining the elimination of the plastic material at this position, so that the rotor parts are able to turn freely in the air-gaps.

In order to achieve an adjustment between the two phases of a two-phase motor, the fixing of the upper stator assembly relatively to the stator support is effected once the phase relation relatively to the lower stator assembly has been determined, for example, in the following manner. The rotor is caused to turn and the voltages induced in the coils 15 and 17 are applied to a phasemeter. The angular position of the upper stator assembly 16 is adjusted in order to bring the induced voltages into quadrature. The assembly 16 is then definitively stuck in the stator support 4.

FIG. 2 illustrates another embodiment, which differs from the foregoing in the following respects. The two stator assemblies 209 and 216 and also the side wall of the stator support 204 have radial openings 220, 221 and 222, respectively. These openings can be seen in the top plan view which is shown in FIG. 3 and which represents a section along the line III—III of FIG. 2.

In this embodiment, the annular spacing sheet 18 of FIG. 1 is replaced by sheet portions, in ribbon form, which pass through the openings 220, 221, 222 and can be withdrawn to the exterior when the stator assemblies and the rotor parts have been fixed. These ribbons are, for example, made of a material named "MYLAR" (Trade Mark), so as to form a spacing element of a well established thickness, which can easily be completely removed, because of the high mechanical resistance of this material. In this case, the annular rotor parts rest, for example, on four points of reference corresponding to the respective openings in the assemblies and the stator support, as shown in FIG. 3.

The rotor support part 206 according to FIG. 2 has a cylindrical peripheral wall 206' and an upwardly open annular hollow 223. At the height of the annular rotor parts, the wall 206' has radial openings 224, 225 of a section slightly larger than the thickness of the rotor parts. For fixing the rotor parts on the supporting part, the hollow 223 is filled with a suitable adhesive which, on being heated at the moment of fixing, passes through the openings 224, 225 distributed along the periphery of the supporting part and effects an easily controllable adhesion.

FIGS. 4 and 5 illustrate another constructional form of the present motor, which has a structure similar to that of FIG. 1. In the assembly according to FIG. 4, a first supporting part 406 is similar to the part 6 in FIG. 1 and presents a series of ribs 406' similar to the ribs 6'. Rotor parts 407 and 408 are stuck on respective second supporting parts 426, 427, which are presented in the form of annular discs, of which the internal diameter corresponds to the external diameter of the cylindrical envelope or shell of the ribs 406'. The rotor parts are fixed beforehand on these supporting rings 426, 427, which will themselves be fixed at the time of the assembly of the motor on the first support part 406. Each

supporting ring 426, 427 has a radial opening, such as 428, at a location situated between two consecutive ribs 406'. The radial openings 428 communicate with the corresponding air gaps in which the respective rotor parts 407, 408 are located, and accessible from the outside of the stator assembly through the space between the neighboring ribs 406.

The example of FIG. 4 shows the use, as spacing element corresponding to the sheet 18 or the MYLAR ribbon 218, of a preformed metallic wire, such as 418, having an essentially circular configuration and being disposed between the ridges of the polar parts of each of the stator assemblies and the respective rotor parts. The preferred form of this spacer wire can be seen in FIG. 5. This wire has a loop 429 and is open at a position diametrically opposite to the latter. The loop 429 is positioned so as to pass through the radial opening of the corresponding support part, such as the opening 428 of the part 426, this enabling the wire to be withdrawn by exerting a traction on the loop through the corresponding space between the adjacent ribs of the supporting part 406. The wire 418 is preferably slightly magnetizable, so that, at the time of assembly, it can be positioned and is held in place on the rotor part, this further facilitating the assembly procedure. The diameter of the circle arcs formed by the wire is about equal to the mean diameter of the pole parts of the stator assemblies, such as 416.

The assembly procedure which has just been described in the aforementioned examples and which makes use of the spacing elements between the pole parts and the rotor parts has, in addition to the advantage from the point of view of the facility of the assembly and of the precision of the air spaces between the parts which cooperate magnetically, the advantage that the total air-gap in which is situated a rotor part of given thickness, is a function of this thickness, which is able to vary slightly in a series production. Now the increase in size of the air-gap for a larger magnet thickness compensates to a large degree for the variation in torque per ampere-turn which would be produced with a constant total air-gap, such as that which is obtained by the conventional assembly procedures.

We claim:

1. A method of manufacturing a synchronous electric motor comprising at least one rotor part of an essentially flat annular form, magnetized in such manner as to present at least one series of magnetic pole, disposed regularly along a flat annular zone, the rotor part being fixed by means of at least one rotor-supporting part on a shaft of the motor mounted so as to be rotatable with respect to at least one stator assembly, the stator assembly comprising at least two stator parts of a magnetically permeable material, forming a variable air-gap along at least a portion of an annular space in which are disposed the magnetic poles of the rotor part, the stator assembly also comprising at least one electric control coil coupled with one or more of said pole parts, wherein the fixing of the rotor part on the rotor-supporting part is achieved in such a way as to permit, at the time of assembly the motor, a positioning of the rotor part in the axial direction and also an angular positioning of the rotor part about the direction of the shaft of the motor comprising the steps of:

first fitting the motor shaft with the rotor-supporting part;
assembling the shaft with the fitted rotor-supporting part with an assembly of pole parts which have to

be disposed facing a corresponding flat annular zone of the respective rotor part, in such manner that the ends of these pole parts, in the axial direction, are disposed in a plane perpendicular to the axis of the motor shaft;

placing the annular rotor part in position by disposing at least one spacer element of determined thickness between the rotor part and the ends of at least one portion of the said pole parts;

fixing the rotor part on the rotor support; and then withdrawing or removing the spacer element from the space between the rotor part and the said pole parts.

2. Method according to claim 1, wherein the spacer element is a sheet of heat-retractable plastic material and wherein the step of withdrawing this sheet is obtained by heating the motor.

3. Method according to claim 2, wherein the heating is obtained by passing an electric current in the control coil of the motor.

4. Method according to claim 1, wherein the spacer element is a sheet of a material capable of being dissolved in a chemical solvent wherein the method further comprises the step of passing a solvent at least into the space between the rotor part and the pole parts.

5. Method according to claim 1, wherein at least one of the stator assembly and rotor-support part comprises at least one access opening communicating with the air space between the rotor part and the pole parts, the opening being accessible from outside of the stator assembly connected with the motor shaft provided with the rotor part wherein the spacer element has the form of a portion of ribbon passing through the said access opening in such manner as to permit its removal through this opening.

6. Method according to claim 1, wherein at least one of the stator assembly and rotor-supporting part comprises at least one access opening communicating with the air space between the rotor part and the pole parts, the opening being accessible from outside of the stator assembly connected with the motor shaft provided with the rotor part wherein the spacer element is a metallic wire of essentially circular form, having a diameter approximately equal to the mean diameter of the magnetized annular zone of the rotor part, this wire having two free ends and a part passing through the said access opening, in such manner as to permit the removal of the wire through this opening.

7. Method according to claim 6, wherein the spacer wire comprises a weakly magnetic material and has two closely disposed free ends, the part passing through the access opening being a loop formed in the continuous part of the wire, and wherein the spacer wire is placed on the annular rotor part before placing the annular rotor part on the ends of the corresponding pole parts.

8. Method according to claim 1 wherein the stator parts forming part of a same magnetic circuit are connected to one another directly or by means of a yoke part, in such manner as to form a magnetic joint constituted by contact surfaces parallel to the axis of the shaft of the motor wherein the method further comprises the steps of disposing that a second spacer element on the face of the rotor part which is opposite to the face comprising the said flat annular zone; placing a second assembly of pole parts the second spacer element, the said assemblies of pole parts respectively forming part of first and second stator parts; and fixing the two stator

parts relative to one another in such manner as to form the corresponding stator assembly.

9. Method according to claim 1 wherein the rotor part of the motor is in the form of an annular disc of small thickness as compared with its external diameter and is magnetized axially and in that the stator assembly comprises pole parts disposed on either side of the rotor part wherein further comprises the steps of disposing a second spacer element on the face of the rotor part which is opposite to the face comprising the said flat annular zone; placing a second assembly of pole parts on this second spacer element, the said assemblies of pole parts respectively forming part of first and second stator parts; and the two stator parts relative to one another in such manner as to form the corresponding stator assembly.

10. Method according to claim 8 wherein a first stator part of the second stator assembly is disposed, directly or by intervention of a spacer element, on the second stator part of the first stator assembly, these said stator parts each comprising a reference surface perpendicular to the axis of the motor shaft.

11. Method according to claim 9 wherein a first stator part of the second stator assembly is disposed, directly

or by intervention of a spacer element, on the second stator part of the first stator assembly, these said stator parts each comprising a reference surface perpendicular to the axis of the motor shaft.

12. Method according to claim 8 wherein a second spacer element is disposed on the face of the rotor part which is opposite to the face comprising the said flat annular zone, and further comprising the steps of placing a second assembly of pole parts is on this second spacer element, the said assemblies of pole parts respectively forming part of first and second stator parts, and fixing the two stator parts relative to one another in such manner as to form the corresponding stator assembly, further comprising at least two axially spaced, coaxial rotor parts, fixed on a same rotor-supporting part, and having at least two stator assemblies each cooperating with a corresponding rotor part wherein a first stator part of the second stator assembly is disposed, directly or by intervention of a spacer element, on the second stator part of the first stator assembly, said stator parts each comprising a reference surface perpendicular to the axis of the motor shaft.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,003,686

DATED : April 2, 1991

INVENTOR(S) : Claude Oudet et al.

Page 1 of 4

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the cover page, in the first line of the name of the invention, before "METHOD" please insert --A--; and in the third line delete "ROTAR" and substitute therefor --ROTOR--.

IN THE FOREIGN APPLICATION PRIORITY DATA

On the cover page, under the above heading, please insert --February 21, 1986 Switzerland PCT/CH86/00024--.

IN THE REFERENCES CITED

On the cover page, under the heading U.S. PATENT DOCUMENTS:

after "Ranseen" please insert --..... 310/46--;
after "Wightman" please insert --..... 310/42--;
after "Inaba et al." please insert --... 310/268--;
after "5/1982 Oudet" please insert --... 310/268--;
after "5/1985 Oudet" please insert --... 310/268--;
after "4/1987 Oudet" please insert --... 310/268--;
and after "7/1987 Oudet" please insert
--..... 310/268--.

**UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION**

PATENT NO. : 5,003,686

DATED : April 2, 1991

INVENTOR(S) : Claude Oudet et al.

Page 2 of 4

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the cover page, under the heading FOREIGN PATENT DOCUMENTS, after "0002503 6/1985" please delete "Italy and substitute therefor --International--; and after "Switzerland" please insert --..... 310/268--.

In column 1, line 2, in the name of the invention, before "METHOD" please insert "A"; and in line 4, delete "ROTAR" and substitute therefor --ROTOR--.

In column 1, line 6, please delete "07/117,220" and substitute therefor --07/117,200--.

In column 1, line 49, please delete the first occurrence of "of" and substitute therefor --or--.

In column 2, line 9, before "perpendicular" please insert --pole parts in the axial direction, are disposed in a plane--.

In column 5, line 7, please delete "406" and substitute therefor --406'--.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,003,686
DATED : April 2, 1991
INVENTOR(S) : Claude Oudet et al.

Page 3 of 4

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In claim 1, line 4, please delete "pole" and substitute therefor --poles--; in line 14, before "said" insert --the--; in line 17, delete "assembly" and substitute therefor --assembling--; and in line 36, please delete "end" and substitute therefor --and--.

In claim 5, line 2, please delete "rotor-support" and substitute therefor --rotor-supporting--.

In claim 6, line 9, please delete "means" and substitute therefor --mean--.

In claim 8, line 3, after "another" please insert --,--.

In claim 9, line 1, after "claim 1" please insert --,--;
and in line 4, after "axially" please insert --,--.

In claim 10, line 1, after "claim 8" please insert --,--.

In claim 11, line 1, after "claim 9" please insert --,--.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,003,686

DATED : April 2, 1991

INVENTOR(S) : Claude Oudet et al.

Page 4 of 4

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In claim 12, line 1, after "claim 8" please insert --,--.

**Signed and Sealed this
Ninth Day of February, 1993**

Attest:

STEPHEN G. KUNIN

Attesting Officer

Acting Commissioner of Patents and Trademarks